

EXECUTIVE SUMMARY

Kapuna (Hawaiian elder and expert fisherman) Buzzy Agard started fishing the Northwestern Hawaiian Islands in the early 1950s. When he first arrived, he spotted a school of large moi (threadfins, an early Hawaiian food fish) and harvested them. He tells that there were “no more the next day, the next week, or ten years later.” He said he learned that “the reefs are fragile and need to be managed with care.”

The United States has jurisdiction over majestic coral reefs covering an estimated 7,607 mi² in the tropical-subtropical belt around the equator. Many of these reef systems support diverse, brightly colored marine life surrounded by emerald seas (Fig. 1); others have been affected by environmental and human-related impacts and need restoration. In the Western Atlantic and Caribbean, **shallow-water**¹ coral reefs are found off Florida², Puerto Rico, the U.S. Virgin Islands (USVI), and in the Navassa Island National Wildlife Refuge near Haiti. In the Gulf of Mexico, reef banks are found on the continental shelf 100 miles south of the Texas/Louisiana Border. In the Pacific, coral reefs occur off the Hawaiian Archipelago, American Samoa, Guam, the Commonwealth of the Northern Mariana Islands (CNMI), Wake Atoll, and another six remote National Wildlife Refuges³. In addition, the Freely Associated States (the countries of the Republic of Palau, the Republic of the Marshall Islands, and the Federated States of Micronesia), included in this report, have some of the richest coral reefs in the world, covering an estimated 4,479-31,470 mi².

In response to growing concerns about the condition of reefs, the United States Coral Reef Task Force⁴ (USCRTF) called for a nationally-coordinated mapping and monitoring program to help track and evaluate the condition of U.S. coral reefs and report to

the Nation every two years. This report is the first effort to collect consistent, comparable scientific information to assess the status of coral reef health.

This first biennial report on the condition of coral reef ecosystems – *The State of Coral Reef Ecosystems of the United States and the Freely Associated States: 2002* was led by NOAA's National Ocean Service. Thirty-eight experts authored the report with information from another 79 contributors. It includes the latest data from published literature as well as unpublished information from coral reef managers and scientists. Information from recent USCRTF mapping, research, monitoring, and conservation initiatives are also included. It has been peer-reviewed by over 100 coral reef ecosystem experts.

This report assesses the condition of reef resources, ranks the relative importance of environmental pressures that have degraded reefs, highlights significant actions taken by USCRTF agencies to conserve coral reef ecosystems, and provides recommendations from coral reef managers to fill information gaps. It forms a baseline against which future assessments will be compared, allowing scientists to track and ultimately predict changes in reef conditions.

Pressures on Coral Reef Ecosystems

Every reef system has suffered varying degrees of impact from

Figure 1. Coral reefs are called the “rainforests of the sea” due to their high biodiversity and threatened status (Photo: Mike White).



¹ Where first used, definitions of scientific terms are highlighted in bold type for the reader's reference. Within this report, **shallow-water** generally refers to those reefs in clear oceanic waters less than 150 feet where ambient light is adequate to support reef-building corals. Where used in the context of mapping habitats, it is the depth aerial and satellite photographic instruments can effectively penetrate the water column, at most 100 ft.

² There are three main areas of coral reefs and banks in Florida – the Florida Keys, the southeastern coast from Monroe to Palm Beach Counties, and the Florida Middle Grounds approximately 100 mi northwest of St. Petersburg.

³ Baker, Howland, Jarvis, Johnston, Kingman, and Palmyra.

⁴ The USCRTF, co-chaired by the Secretary of Interior and the Secretary of Commerce, includes the heads of 11 Federal agencies and the Governors of 7 States, Territories, and Commonwealths with responsibilities for coral reefs. The Task Force also includes representatives from the U.S. All-Islands Coral Reef Initiative and the Pacific Freely Associated States.

natural environmental and human disturbance (refer to Table 2 in the National Summary). A burgeoning population of 10.5 million now resides in coastal counties and islands next to U.S. coral reefs; another 203,000 reside on islands of the Freely Associated States. The coastal development (schools, roads, marinas, and other businesses) needed to support the population and the tourists that flock to these seaside communities is a major threat. Add the recreational and commercial use of reef resources, and it is a wonder that beautiful reefs can still be found in all jurisdictions.

Changing climate, coastal development, **overfishing**⁵, disease, and natural events such as tropical storms may interact to increase overall reef degradation.

Global Climate Change and Coral Bleaching⁶ – The ultimate long-term environmental threat to coral reef ecosystems is global climate change that many believe is linked to the dramatic increase of coral bleaching in the past decade. Bleaching varies regionally, locally within a reef⁷, and among species. It also coincides with elevated water temperatures associated with El Niño and La Niña events.

Although most U.S. reefs escaped major damage from the largest coral bleaching event on record (1997-1998), reefs off Florida, Palau, and Palmyra were devastated (Fig. 2). During this bleaching event, an estimated 16% of the reef corals were destroyed world-wide.

Fishing – Historically, the broad array of reef fishing activities has great cultural, economic, and recreational value. This report calculates that U.S. commercial reef fisheries today are worth over \$137.1 million to fishermen. The gross value estimated for commercial fisheries in the Freely Associated States is another \$109.8



Figure 2. A bleached coral in Florida (Photo: Harold Hudson).

million. According to coral reef managers, the greatest human-related impacts on the broadest scale are over-harvesting of reef resources and fishing-associated habitat destruction.

Overfishing threatens Florida, Puerto Rico, the USVI, the Main Hawaiian Islands, American Samoa, and to a lesser degree reefs around other populated islands. In the South Atlantic, Gulf of Mexico, and

Caribbean, NOAA identified 23 reef fish as overfished and concluded there was too little data to determine the status of another 232 species. As a result, four species of Western Atlantic grouper have been added to the list of candidate species under the Endangered Species Act (Fig. 3).

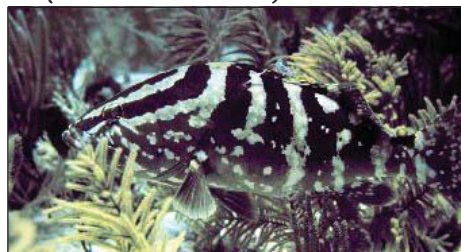
Managers from Florida, Puerto Rico, USVI, Hawai'i, and the offshore coral banks in the Gulf of Mexico are particularly concerned that certain types of fishing gear, particularly fish and lobster traps and large gill nets, may physically damage and degrade reef habitat.

Diseases – Over the last few decades, there has been a worldwide increase in reports of new diseases. Disease appears to be more prevalent near human population centers. While there is no direct correlation, long-term, low-level stress from poor water quality, elevated water temperatures, overfishing, and other factors may make reef organisms more susceptible to disease.

The Caribbean region has much higher incidences of disease, where outbreaks of a number of diseases have contributed to mass mortalities of corals, fish, sea fans, sea urchins, sponges, sea-

grasses, and other organisms. One of the worst of these, a disease killed over 90% of the mature long-spined sea urchins throughout much of the Caribbean in the early 1980s. Since then, these urchins have recovered to only about 10% of their original numbers on reefs off Florida, Puerto Rico, and the USVI. Of

Figure 3. The Nassau grouper is a candidate for protection under the Endangered Species Act (Photo: NOAA's NMFS).



⁵ As used throughout this report, the terms **overfishing** and **overfished** are generally the same as defined for U.S. federal fisheries – a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis (Magnuson-Stevens Fishery Conservation and Management Act, Pub. Law 94-265, 16 U.S.C.1801 Sec. 2).

the many coral diseases to emerge over the last 20 years, white-band disease is one of the most virulent, killing up to 90-95% of the elkhorn and staghorn corals off St. Croix, Puerto Rico, and south-eastern Florida by the 1990s.

With the exception of cancerous tumors infecting green sea turtles⁸ off the Main Hawaiian Islands, disease in the Pacific Islands is low to moderate.

Tropical Storms – With eight hurricanes in the past 20 years nearly destroying staghorn and elkhorn coral populations, USVI managers consider tropical storms a major threat (Fig. 4). Elsewhere, reef corals have more resilience. On many Pacific islands, normal heavy wave action removes relatively fragile vertical branches of corals. As a result, throughout the region, low-growing encrusting and massive growth forms of coral prevail.

Because they lie in the Western Pacific Monsoon Trough, Guam and the CNMI have these low-profile reefs. About half the typhoons that develop in the Pacific pass near or directly hit these islands, yet the extensive living reef structure that protects them sustains surprisingly little damage even when a super typhoon passes directly overhead.



Figure 4. Coral rubble produced by storm damage (Photo: Matt Kendall).

Coastal Development and Runoff – Tropical climates, colorful reefs, and clear waters draw permanent residents and tourists to seashores. To sustain the influx, additional housing, hotels, and other coastal development (e.g., roads, airports, hospitals, schools) are needed, all of which result in runoff and sedimentation during and after construction. Runoff and sedimentation from coastal development have degraded coral reef ecosystems off southeastern Florida and the Keys, Puerto Rico, the USVI, most of the Main Hawaiian Islands, Guam, and the CNMI.

Runoff and sedimentation also occur in rural areas where forests have been removed for agriculture.

Near-shore reefs off high Pacific islands in American Samoa, the CNMI, and Palau experience runoff and sedimentation during tropical storms. Although less widespread than overfishing, runoff and sedimentation are of considerable concern to managers in all jurisdictions.

Coastal Pollution – Managers from eight jurisdictions consider coastal pollution a major threat to their coastal coral reef ecosystems. Toxic chemicals and excessive nutrient enrichment are mostly limited to relatively small areas within canals, harbors and marinas, and near sewage disposal sites. There are polluted ‘hot spots’ near reefs off Florida, Puerto Rico, the USVI, some islands within the Hawaiian Archipelago, American Samoa, Guam, and the CNMI. High levels of toxic chemicals have been found in the tissues of reef wildlife off urbanized areas and several of the Northwestern Hawaiian Islands.

Harvesting and Trade in Corals and Live Reef Species

The trade in live reef fish, chunks of coral, and invertebrates for aquariums has grown rapidly over the last decade, raising concerns among scientists and managers, particularly those in Hawai‘i (Fig. 5). The United

States is the largest importer of ornamental coral reef species, responsible for around 70-95% of the global trade in coral and ‘live rock’ and nearly half

Figure 5. Managers in Hawai‘i are concerned about the potential effect of the aquarium trade on the endemic masked angelfish (Photo: James Maragos).



⁶ **Bleaching** is a condition whereby the algae (called zooxanthellae) living in the epidermal tissue of most reef corals are expelled after prolonged exposure to certain environmental conditions (e.g., elevated temperatures). The color of the coral primarily comes from the zooxanthellae, so the coral whitens when they are expelled, leaving only the white carbonate color of the coral skeleton. This condition can be temporary if the zooxanthellae return within a few days, if not, then coral mortalities can be high.

⁷ Incidences and mortalities from bleaching are generally higher at shallower depths and lower on reefs within estuaries.

⁸ Fibropapilloma disease.



Figure 6. Two grounded fishing vessels in Pago Pago Harbor, American Samoa (Photo: James Hoff).

of the total worldwide trade in marine aquarium fishes. Most of the ornamental fish and invertebrates originating from U.S. waters come from Hawai'i and Florida, with smaller numbers originating in Puerto Rico, the USVI, and Guam. Since 1999, these jurisdictions have taken action with new studies, regulations, **marine protected areas**⁹ (MPAs), **no-take zones**, and landmark legal settlements.

Alien¹⁰ Species – Only recently have alien species been recognized as a threat to ecosystems. Non-native organisms are introduced to near-shore reefs from ship hull fouling and ballast water, aquarium releases, as well as purposeful introductions for science and aquaculture. Besides the organisms, each may have diseases or parasites that can devastate native species. Although their impacts are not well studied, coastal **invasive** species are a major concern in the Hawaiian Islands with its many rare and endangered species.

Boats, Ships, and Groundings – Boat traffic threatens reef structure and associated wildlife. Groundings, anchor damage, and propellers speeding through shallow waterways are some of the most destructive chronic human factors (Fig. 6). They cause significant localized damage to shallow-water coral reefs. The increasing number of large ship and small boat groundings is a major threat off Florida, the USVI, and the Main Hawaiian Islands, and of moderate concern along other populated coasts.

Tourism and Recreation – The economic value of coral reefs is significant. But growth within the

tourist industry has serious ecological ramifications for coral reef ecosystems off Florida, Puerto Rico, USVI, the Main Hawaiian Islands, Guam, and Palau. This report calculated that annually 45 million visitors come to seaside and live-aboard accommodations to dive, fish, and otherwise enjoy U.S. coral reefs. Reef-related tourism generates an estimated \$17.5 billion annually in local income and sales for U.S. States, Commonwealths, and Territories. An additional 113,000 tourists visit the Freely Associated States, spending over \$84.8 million annually. With so many tourists visiting coral reefs, damage is inevitable (Fig. 7).

Managers from eight jurisdictions consider the impacts from tourism and associated recreational activities a medium-to-high concern for near-shore coral reef ecosystems.

Marine Debris¹¹ – Transported by ocean currents over long distances, marine debris snags, smothers, and breaks coral colonies, and kills marine wildlife (e.g., endangered Hawaiian monk seals, sea turtles, and island sea birds, Fig. 8) through either entanglement or ingestion. Marine debris is a matter of high concern for the coral reef managers from the Northwestern Hawaiian Islands and the Federated States of Micronesia. Since 1999, multi-agency clean-up activities have removed over 150 tons of debris from Hawaiian Island beaches and near-shore reefs, but much still remains.

Offshore Oil and Gas – Some coral reefs are located near petroleum extraction facilities; others are threatened by their close proximity to oil

Figure 7. Unaware of the damage they cause, tourists can literally trample the coral reefs that they come to see (Photo: William Harrigan).



⁹ Defined in the Marine Protected Areas Executive Order 13158, an **MPA** is "an area of the marine environment that has been reserved by Federal, State, Territorial, Tribal, or Local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein" (*Federal Register* 2000). Some MPAs have **no-take provisions, zones**, or the entire MPA may be designated a **reserve**; in these, resource extraction has been prohibited to protect biodiversity and/or to enhance certain fish stocks.

refineries, storage facilities, or shipping lanes frequented by oil tankers. Potential impacts include accidental spills, contamination by drilling-related effluents and discharges, vessels anchoring when placing pipelines, drilling rigs and production platforms, seismic exploration, use of chemical dispersants in oil spill mitigation, and platform removal.

Within a 2.9 mi² radius of the Flower Garden Banks National Marine Sanctuary in the northwestern Gulf of Mexico, there are currently ten oil production platforms with approximately 100 mi of pipeline. Within the boundary of the East Flower Garden Banks, there is a gas production platform. To date, none of these have been a problem.

Other Physical Impacts to Coral Reefs –

There are other human-related impacts to reef structure of concern to managers. Although no longer legal in U.S. waters, dynamiting reefs to collect fish remains a problem in the Indo-Pacific region. Live munitions aboard some sunken World War II relics have been found and used by fishermen to harvest reef fish.

Other wrecks may be a danger to recreational divers and local fishermen. For safety reasons, the U.S. Navy recently detonated live depth charges found on a WWII Subchaser that had wrecked on a now popular CNMI reef.

Between 1946 and 1958, the United States used Eniwetok and Bikini Atolls in the Marshall Islands to test 67 nuclear devices. The craters of many of these blasts can still be seen and the effects on reef structure are evident in shallow waters.

Where national security training exercises and live-fire activities have been conducted (Vieques, Puerto Rico; Farallon de Medinilla, CNMI; Kaho‘olawe and Kaula Rock, Main Hawaiian Islands), managers are concerned about impacts of bombing and unexploded ordnance on reefs.

National Assessments of Coral Reef Ecosystems

Every U.S. reef system has sustained impacts from environmental and human disturbance, but all jurisdictions still have some reefs in good to

excellent health. Many scientists consider reef systems in Florida and the U.S. Caribbean to be in the poorest condition, mostly because they are close to dense populations and have been repeatedly hit by a series of hurricanes, diseases, and various chronic human-induced impacts. Pacific reefs, even around urbanized islands, are in significantly better condition. This is due in large part to the fact that many lie off isolated islands and atolls and are surrounded by deep water with prevailing strong currents, upwelling, high waves, and tropical storms that flush the reefs with clean, cool water.



Figure 8. Seabirds feeding among plastic debris (Photo: NOAA Library).

Currently, there is relatively little quantitative information available assessing temporal and spatial trends in coral reef condition. Most coral reefs have yet to be mapped and their resources characterized. Little comparable data are available on coral reef function, structure, and condition.

Prior to 2000, the comprehensive mapping and long-term monitoring needed to prepare a national assessment were only available for a few locations¹². Since FY02¹³, with considerable support from the U.S. Congress, NOAA started a major mapping initiative and has provided substantial grants to island agencies to build local capacity for long-term monitoring using comparable sampling methods and protocols. The authors of this report have committed to participating in a nationally-coordinated Coral Reef Monitoring Network to develop criteria, indicators, and metrics for a ‘report card’ to track changes in the condition of coral reef ecosystems. It will also allow them to

¹⁰ When established (i.e., successfully reproducing), a species purposefully or unintentionally introduced is termed **alien** or **exotic**. Alien species (and some indigenous species) that have economic, environmental, and human health impacts are also termed **invasive**.

¹¹ Fishing gear and other remnants of human activities coming from recreational and commercial vessels, storm drains, industrial facilities, and waste disposal sites.

¹² The Florida Keys National Marine Sanctuary and the Flower Gardens National Marine Sanctuary off Texas.

¹³ The federal fiscal year; in this instance, FY02 is from October 1, 1999 to September 30, 2002.



Figure 9. Blade fire coral has been particularly hard hit by coral bleaching in Florida (Photo: William Harrigan).

evaluate the effectiveness of conservation measures for the next biennial report, scheduled for 2004.

The following regional summaries are largely qualitative reports by the managers and scientists who are most familiar with the reef resources. For more details, see the jurisdictional reports that follow the National Summary.

Florida – Florida's coral reefs are extensive. They have the greatest number of tourists/visitors of any U.S. jurisdiction, and consequently have substantial human impacts, particularly along the south-eastern coast and in the Florida Keys. In general, reef health is declining in southeastern Florida and the Keys, as evidenced by species fluctuations, decreases in coral coverage, and disease. Over the past 20 years, coral bleaching has increased in both frequency and duration, often with high mortality. Particularly massive bleaching events in 1990 and 1997-1998 were responsible for the 80-90% mortality of blade fire corals on shallow-water reefs (Fig. 9).

Monitoring in the Florida Keys National Marine Sanctuary showed both coral reef abundance and diversity were declining – coral cover decreased 37% over the past five years. This was preceded by even more dramatic declines in the 1980s and early 1990s. On the other hand, deeper reefs off the Tortugas Ecological Reserve and the Florida Middle Grounds are in excellent condition.

In the Keys, 23 of 35 species of groupers, snappers, wrasses, and grunts are overfished, while five fish species from the Florida Keys are considered at risk of extinction. Nearby Florida Bay has

another six at-risk fish species. In Biscayne National Park, 26 of 34 fish species are considered overfished.

There is evidence that Sanctuary-designated fully protected zones have already replenished stocks for several over-harvested species. On these reefs, average size and abundance of large groupers, snappers, and spiny lobsters have increased in the past few years.

Turbidity, contaminants, and nutrient enrichment can periodically be high and vary geographically¹⁴. Toxic contaminant 'hot spots' have been found in the sediments of both Biscayne and Florida Bays.

The recreational fishing fleet in South Florida has grown at a near exponential rate since 1964 (a 444% increase in recreational boats from 1964 to 1998) with no limit on the number of boats allowed to fish.

Puerto Rico – Due to its rapidly growing population and thriving tourism, human pressures on Puerto Rican coral reefs are some of the most severe in the Caribbean. Accelerated urban and industrial coastal development over the last four decades, with the corresponding coastal development, sewage discharge, and sediment runoff during and after construction, have all degraded the condition of nearby reefs.

Staghorn and elkhorn coral populations have declined in most locations over the last 25 years from hurricane damage, white-band disease, and coral-eating mollusks. Fishery resources show the classic signs of overfishing – reduced total landings, declining catch-per-unit-effort, smaller fish taken, and recruitment failures. Reef fisheries have plummeted during the last two decades; between 1979 and 1990 they dropped 69%.

Shallow-water coral reefs off La Parguera on the main island of Puerto Rico and off the islands of Desecheo and Vieques have the highest abundance and cover of living corals in the Commonwealth, but even those have been stressed significantly.

U.S. Virgin Islands (USVI) – Over the past 20 years, near-shore coral reefs off the USVI have suffered a series of natural disasters and been exposed to increasing chronic impacts from island residents and tourists (Fig. 10). Compounding the devastation from being hit by eight hurricanes with

¹⁴ For example, higher nutrient concentrations are reported in the Middle and Lower Keys than in the Upper Keys and the Dry Tortugas.

little time to recover, shallow-water reef corals have suffered high mortality from coral diseases, particularly white-band disease. On some reefs, living elkhorn coral cover has fallen from 85% to 5%. Major coral bleaching events occurred in 1987, 1990, and 1998, but generally mortality was not high.

Macroscopic algae, covering about 5% of the bottom before Hurricane Hugo, are now periodically very abundant, averaging over 30% cover in some months. This is probably the result of decreased algal grazing after the loss of long-spined sea urchins in the early 1980s and the overfishing of **herbivorous fishes**¹⁵. Dredging, sand extraction, pier construction, and sewage effluent have all impacted USVI reefs, especially those off St. Thomas and St. Croix.

Overfishing is a serious problem throughout the USVI and has had a profound effect on finfish and invertebrates. After depleting the desirable species of groupers¹⁶, fishers began targeting smaller species. In general, fisheries are close to collapse, even within marine protected areas.

Flower Garden Banks – The coral reefs in the Flower Garden Banks National Marine Sanctuary are in excellent condition, largely because 1) the banks are located well offshore, 2) they generally lie deeper (the reef platform is around 55-100+ ft from the surface), and 3) they are far from human settlement.

Coral cover on the bank platform averages 47% and has not significantly changed since monitoring began in 1972 (Fig. 11). Disease is relatively low, as is coral bleaching; neither has resulted in significant mortality. Macroalgal populations have

Figure 11. Coral cover at the Flower Garden Banks has not changed significantly since the 1970s (Photo: Frank and Joyce Burek).



¹⁵ Fish that primarily consume plant material such as algae.

¹⁶ By the 1970s, several spawning aggregations of Nassau grouper had been completely decimated.



Figure 10. Increased tourism has brought more cruise ships to USVI harbors (Photo: Ralph Kresge).

historically been low, with cover estimates generally less than 5%.

Fishing pressure is not intense at this time. Commercial long-line fishing for snapper and grouper occurs along all of the continental shelf edge; target areas for this activity are typically the deeper portions of the bank structure, away from the shallower coral reef platform.

The Main Hawaiian Islands (MHI) – With a few exceptions and despite changes in coastal land use, near-shore reefs around the eight MHI remain in relatively good condition. Coral reefs suffer from degradation related to human population growth, urbanization, and development. Major sources are ocean outfalls, urbanization, massive coastal recreational development (hotels, golf courses, etc.), and marine invasive species, especially macroalgae and the red mangrove. Previously, ranching, plantation agriculture, and military construction impacted reef condition.

There are strong indications of overfishing of the majority of fish and invertebrates. Recently there has been concern regarding the expanding live marine ornamental trade for home aquaria. Fishing pressure in heavily populated areas appears to exceed the capacity of these resources to renew themselves. The abundance of reef fishes in areas where fishing is allowed is substantially lower than in areas where it is prohibited. There are numerous no-take marine protected areas off MHI shores; some of the larger ones have been shown to be effective in replenishing local fish stocks, but the rest may be too small to serve as ecosystem refuges (Fig. 12).

For almost 10 years now, high nutrient levels and algal blooms have been recurring on reef flats off the southern and western coasts of Maui. Ship traffic, proximity of reefs to harbor entrances, and more vessel groundings have resulted in more oil spills. High concentrations of toxic chemicals have been measured in near-shore sediments and in the tissues of a variety of coastal marine wildlife.

The Northwestern Hawaiian Islands (NWHI)

The situation is very different in the far-dispersed, sparsely populated islands to the northwest of the MHI. The NWHI islands and atolls are unique among Pacific reefs because of their near-pristine condition, preponderance of large fish, general lack of disease and bleaching, and the abundance of **endemic**¹⁷ species. High numbers of shallow-water fish that are all but absent in the MHI as well as substantial populations of large **apex predators**¹⁸, especially jacks and sharks, indicate these reefs are healthier than most.

Recent reef fish surveys throughout the Hawaiian Archipelago revealed that fish abundance in the NWHI averaged 260% more than that of the MHI; the average weight of apex predators was 570% greater. By weight, most of the dominant species in the NWHI were either rare or absent in the MHI.

The major anthropogenic impact on NWHI reefs is marine debris, mostly nets, plastics, and other trash transported by currents from fleets fishing in distant waters (Fig. 13).

The existing Hawaiian Islands and Midway National Wildlife Refuges and now the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, make these reefs the most highly protected. Furthermore, the State of Hawai'i is presently evaluating its option of developing State fishery management areas in the NWHI.



Figure 12. The Waikiki Marine Life Conservation District's small size and urban location may hinder its capacity to fulfill its conservation objectives (Photo: Michael Theberge).

American Samoa – Coral reefs off American Samoa are recovering from natural disasters – a crown-of-thorns starfish invasion (1979, Fig. 14), three hurricanes (1986, 1990, 1991), and a period of warm weather that caused massive coral bleaching (1994). Added to this are chronic human-induced impacts in populated areas like Pago Pago Harbor.

Coral recovery from the natural disturbances has been excellent through 2001. Information is limited, but with a few exceptions, the algae found around the islands are indicative of a low nutrient environment¹⁹ and/or heavy grazing by herbivores.

Harvested species such as giant clams and parrotfish are overfished; there is heavy pressure on surgeonfish, and there are fewer and smaller groupers, snappers, and jacks. The endangered hawksbill turtle is in serious decline from illegal harvest and loss of nesting habitat.

Fish are contaminated with heavy metals in some areas, particularly in Pago Pago Harbor.

Guam – The health of Guam's coral reefs ranges from excellent to poor, depending on adjacent land use, human accessibility, location of ocean outfalls and river discharges, recreational pressure, and

Figure 13. Marine debris on a coral reef at Kure Atoll (Photo: James Maragos).



¹⁷ Species with restricted geographic ranges; these rare species are unique to a specific area, such as an embayment, an island, or a group of islands.

¹⁸ Those large meat-eating species at the top of an ecosystem food chain or web.

¹⁹ Indicating low pollution in these areas.

²⁰ Typhoons, crown-of-thorns starfish outbreaks, and earthquakes.

²¹ Underground water originating from upland sources of fresh water that percolates through coastal sediments along the beach or just offshore. Where this occurs, less saline, nutrient-laden water will kill reef species.

water circulation patterns. There are indications of an overall reduction in Guam's coral species diversity. Reefs impacted by natural disturbances²⁰ have not recovered in specific areas.

Apra Harbor is home to a large U.S. Naval facility and the Guam Port Authority. Within the bay, corals and reefs have been impacted by freshwater runoff, sediments, grounding by ships, and thermal discharges from the Island's main power generation facilities. A variety of pollutants have been found in harbor sediments.

Agana, Tumon, and Piti (also known locally as Tapungun) Bays have heavy human use. The inner areas of these bays are in relatively poor condition, affected by discharges from land as well as impacts from recreational activities. Agana and Tumon Bays are centers for tourism. West Agana has a sewage treatment plant built on the reef flat that had a pipe discharge in 60 ft of water (upgrades are underway). **Coastal aquifer** discharges²¹ usually have high levels of nutrients²², especially at the start of the rainy season. These are responsible for chronic algal **blooms**²³ in Agana Bay and can cause **red tides** in Tumon Bay.

While the crown-of-thorns starfish have occurred in small-to-moderate numbers over the past few years, a substantial population of juveniles now is cause for concern about the potential for a future outbreak.

As indicators of overfishing, fish populations and catch-per-unit-effort have declined more than 50% over the past 15 years. Large reef fish are rare.

Commonwealth of the Northern Mariana Islands

Islands – Generally, the CNMI reef ecosystems are in excellent to good condition. Reefs adjacent to the populated southern islands of Saipan, Tinian, and Rota receive most of human impacts from development, population growth, fishing, and tourism.

Although coral reef species were devastated by a major crown-of-thorns starfish outbreak in the late 1960s, most of the affected reefs appear to have

recovered. CNMI coral reefs were spared the impacts of the 1998 coral bleaching event; however, bleaching is now a major concern.

Based on qualitative assessments, CNMI's populated southern reefs are all overfished at some level; fish populations on the mostly unpopulated northern reefs are generally in excellent condition.

U.S. Remote Insular²⁴ Reefs – These reefs off remote and largely uninhabited atolls and islands remain relatively pristine. They have experienced few human-induced pressures outside of long-distance fishing. Disease is low; except for Palmyra Atoll, the same is true for coral bleaching.



Figure 14. Crown-of-thorns starfish outbreak in American Samoa (Photo: Charles Birkeland).

Since the late 1800s, there has been little fishing pressure on any of these reefs. Shallow-water reef fish communities exhibit high density and have substantial populations of large snappers, groupers, and herbivores.

Republic of the Marshall Islands

The RMI coral reef ecosystems are generally in good to excellent condition. Even the reefs used for the 67 nuclear tests have recovered well, though perhaps not as completely as some scientists have reported. There is little data on the diversity of reef organisms and only recently there have been assessments of general reef condition.

With their low elevation (average elevation of 7 ft), the entire Marshall Island chain is in danger of being submerged with even moderate sea level rise from global climate change.

Federated States of Micronesia – Reef condition throughout the FSM is generally good to excellent. Most of the reefs around the low islands are quite healthy. Reefs around the populated islands of Pohnpei, Chuuk, Kosrae, and Yap vary in condition, but are generally good with live coral cover ranging from 20-70%.

The primary human impacts come from fishing pressure and ship groundings. Overfishing has been documented as a result of foreign commercial activities. Destructive fishing practices, including

²² From agricultural chemicals.

²³ A sudden population explosion of algae within a relatively limited area, often the result of increased nutrients in the water. A **red tide** is a harmful bloom of microscopic algae (e.g., dinoflagellates) that often imparts a reddish or brownish hue to the water.

²⁴ Another term for island or atoll. These are the Navassa Island National Wildlife Refuge in the Caribbean near Haiti, Wake in the Marshall Islands, and the Pacific National Wildlife Refuges of Johnston, Howland, and Baker in the Phoenix Islands; Jarvis; Johnston; and Kingman Reef and Palmyra in the Line Islands.

the use of explosives taken from the wrecks, have caused local reef damage.

Republic of Palau – Before the 1997-1998 bleaching event in Palau, the remote reefs were in good to excellent condition, with the most diverse coral fauna of any area in Micronesia (over 425 stony coral and 120 soft coral species). Live coral cover generally ranged from 50-70% (Fig. 15). However, the event severely affected most shallow-water reefs; on some reefs 30-100% of the *Acropora* coral died. Crown-of-thorns starfish have also been a problem for Palauan coral species, and on many reefs they are targeting the few *Acropora* corals that survived the bleaching event.

Reefs closer to population centers or areas where development is occurring show signs of degradation and are not as healthy as the remote reefs. Eutrophication in Malakal Harbor has been directly linked to fishing vessels anchored there, as fishers remain onboard with inadequate sanitation or waste disposal facilities.

Fish populations off the main islands of Palau²⁵ are showing signs of overfishing compared to the southwestern islands where there is less fishing pressure. Around the main islands of Palau, highly desired species of fish are either absent or present in low numbers.

Temporal Trends – In places where there has been credible long-term monitoring, there are alarming temporal trends. These include decreasing live reef cover, increasing coral disease and bleaching with significant mortality, and overfishing. Mostly due to hunting over the last century, all sea turtle species and a number of marine mammal species are in danger of extinction (Fig.

Figure 15. A Palauan coral reef with high percent coral cover (Photo: James McVey).



Figure 16. The Hawaiian monk seal and green sea turtle are both endangered species (Photo: George Balazs).

16). Now these are being protected under provisions of the Endangered Species Act and the Marine Mammal Protection Act.

Where no-take reserves have been enforced and monitored, there are increasing numbers and sizes of harvested fish and invertebrates.

Spatial Trends – Seven tables in the main report present what is known about the condition of coral reef ecosystems in the 13 jurisdictions. These will be the baseline for future assessments and biennial reports on coral reef ecosystem condition, and may be the basis for predicting ecosystem change.

Without a single master list of inventoried species and with significant information gaps on many of these tables, the effort to develop biennial reports on coral reef condition is limited. To remedy this, NOAA and its partners, initiated a pilot Hawaiian prototype project that should result in a computerized list of all U.S. coastal marine species in the near future. Further, NOAA's mapping initiative and its cooperative grants to island agencies that support long-term monitoring should fill many of the remaining information gaps.

Agency Responses to Conserve Coral Reef Ecosystems

In 1998, growing scientific evidence and global concerns for the health of coral reefs prompted the U.S. Government to issue a Presidential Order for the protection of coral reefs (E.O. 13089). It also established the USCRTF.

In 2000, the USCRTF issued its *National Action Plan to Conserve Coral Reefs* (National Action Plan). Congress appropriated \$8 million in FY00, \$27 million in FY01, and \$34 million in FY02 to

²⁵ The most diverse reef ecosystem under U.S. jurisdiction, with a total of 1,278 known reef fish species.

the Department of Commerce and another \$10 million annually from FY00-02 to the Department of Interior to enhance coral reef conservation activities. In addition, the new Coral Reef Conservation Act of 2000 further integrated efforts by Federal, State, and Territorial agencies to map, monitor, conduct research, restore, and manage U.S. coral reef ecosystems. The USCRTF National Action Plan recommended preparing biennial reports on the State of American Coral Reef Ecosystems. This is the first.

The National Action Plan presented 13 action items that, if followed, will improve scientific and community understanding of coral reefs and reduce the adverse impacts of human activities. The agencies of the USCRTF have made significant progress in these areas since 2000, though much still remains to be done.

Map all U.S. Coral Reefs – The National Action Plan called for mapping all shallow-water coral reef ecosystems by 2009. Digital maps of shallow-water habitats off Puerto Rico, USVI, and most of the Florida Keys have been completed. Aerial photographic images for portions of Hawai‘i, and satellite images for most of the rest of the U.S. Pacific island shallow-water reefs have been acquired, a first step for mapping these reefs. In 2001, NOAA characterized and mapped habitats of the deep *Oculina* coral reefs off the eastern coast of Florida using submersibles and multi-beam sonar.

Assess and Monitor Reef Health – The National Action Plan called for a nationally-coordinated Coral Reef Monitoring Network that will provide regular assessments of reef health as well as initiate new monitoring to fill information gaps. Now in its third year of NOAA leadership and funding, the National Coral Reef Program has provided cooperative grants to state and island agencies to build local capacity for assessing and monitoring local reefs. Other NOAA and DoI grants have supported related research, monitoring, and education projects.

A number of shallow-water rapid ecological assessments (REAs) of coral reef ecosystems have been conducted since FY00 by agency and non-governmental scientists. Of these, the 2000 NOW-RAMP expedition was the most comprehensive (birds, marine mammals, fish, invertebrates, and



Figure 17. Diver assessing coral species at French Frigate Shoals during the NOW-RAMP Expedition (Photo: James Maragos).

sediment contaminants were surveyed throughout the length of NWHI, Fig. 17). Additionally, the U.S. Fish and Wildlife Service (USFWS) and NOAA conducted initial REAs of reef ecosystems off the U.S. Remote Insular Reefs. Also in cooperation with NOAA, the USFWS established sites for long-term coral reef monitoring at each of the REA islands as well as at the Midway, Rose, and Johnston Atoll National Wildlife Refuges.

A variety of volunteer programs also monitor the reefs as part of the Coral Reef Monitoring Network. They enhance coverage of the monitoring conducted by agency and non-governmental scientists.

Conduct Strategic Research – Additional research is needed to better understand coral reef ecosystems and help determine what can be done to protect and restore them. Funding for many applied research projects on coral reef ecosystems has gone through the Hawai‘i Coral Reef Initiative Research Program, the National Coral Reef Institute, the National Center for Coral Reef Research, NOAA’s Sea Grant Program, several of NOAA’s National Underwater Research Centers, and the National Science Foundation.

NOAA, USEPA, and DoI created a new Coral Disease and Health Consortium (CDHC) in 2000. The CDHC will conduct and coordinate disease research, track outbreaks of coral disease, and characterize disease agents impacting coral reef ecosystems.

Understand Social and Economic Factors – The social, economic, and cultural dimensions must be incorporated into any broader conservation



Figure 18. A socioeconomic study of the Flower Garden Banks National Marine Sanctuary evaluated the economic impact of dive tourism (Photo: Emma Hickerson).

strategy. The Global Coral Reef Monitoring Network released a *Socioeconomic Manual for Coral Reef Management*, edited by NOAA staff, in November 2000. Building on that manual, NOAA staff assisted in regional socioeconomic training workshops in East Africa, South Asia, and in the Caribbean. In 2001, a socioeconomic assessment of the financial impact of the Florida Keys National Marine Sanctuary's fully protected zones on commercial fishing and track trends in recreational tourism and its relationship to the local economy was completed. Another socioeconomic study has also been completed for the Flower Gardens Banks National Marine Sanctuary (Fig. 18). In 2002, similar studies were commissioned for reefs off Hawai'i, American Samoa, and Guam.

Expand and Strengthen Marine Protected Areas (MPAs) – There is an urgent need to protect the most important reef habitats from further decline by strengthening and expanding a network of coral reef marine protected areas (MPAs) and no-take reserves. The goal was to protect at least 5% of all U.S. coral reefs and associated habitat types in each major island group and Florida with no-take provisions by 2002, at least 10% by 2005, and at least 20% by 2010. Until all coral reef ecosystem habitats have been mapped, the percentage of these reefs currently protected cannot be accurately calculated.

Significant new MPAs and no-take reserves have been established over the past several years off Florida, Puerto Rico, USVI, Hawai'i, CNMI, and in the Navassa, Palmyra Atoll, and Kingman Reef National Wildlife Refuges (see Table 10 for a full listing by area and percentage, Fig. 19).

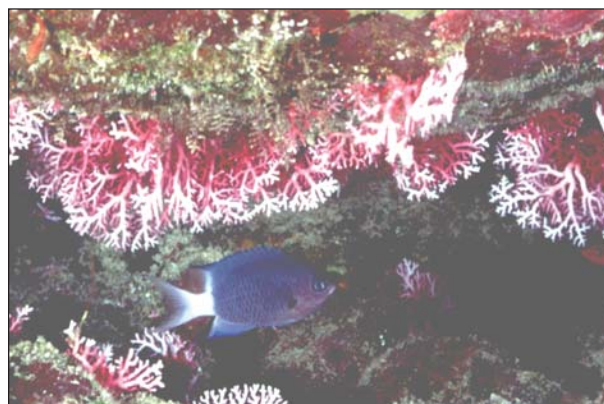
But there is still a long way to go. Currently, there is full no-take protection for 1,329 mi² of U.S. coral reef ecosystems; in Palau, another 25.2 mi² of reefs have full protection. Three jurisdictions currently exceed the 2010 goal: the U.S. Remote Wildlife Refuges (30.3%), Guam (approximately 28%), and the Northwestern Hawaiian Island National Wildlife Refuge (21.4%). With the exception of the USVI, elsewhere no-take protection is only 5% or less of the total reef ecosystem.

Much has been done over the past few years by USCRTF agencies to strengthen MPAs, but current MPAs and new no-take areas cannot be effective without enforcement. This critical need is recognized by all jurisdictional managers as well as the many authors and collaborators who helped prepare this report.

Reef Fishing and Collecting for Aquaria – The National Action Plan called for reducing the impacts of fishing (e.g., overfishing, **bycatch**²⁶, destructive fishing practices) and the over-harvesting of reef organisms for the aquarium trade (Fig. 20). Since FY00, USCRTF agencies have taken a number of important actions to reduce the impacts of fishing and aquarium collection on coral reefs, including banning the taking of live coral, prohibiting reef fishers from using explosives and poisons, and designating no-take zones. Several jurisdictions banned SCUBA spearfishing. Others are conducting studies and planning to revise regulations relating to the capture of live organisms for aquariums.

As an alternative to wild capture, NOAA's National Sea Grant Program has funded research projects

Figure 19. A coral reef in the recently established Kingman Atoll National Wildlife Refuge (Photo: James Maragos).



²⁶ Fish that are harvested but not sold or kept for personal use (Magnuson-Stevens Fishery Conservation and Management Act, Pub. Law 94-265, 16 U.S.C.1801 Sec. 2). It includes economic discards and regulatory discards but not fish released alive under a recreational catch and release fishery management program.

in Puerto Rico, Florida, Texas, and Hawai'i to cultivate coral reef species. Over 20 species of fish, crustaceans, mollusks, and corals are now commercially grown.

Reduce Impacts of Coastal Use – Federal and State permitting and management programs for coastal development activities that impact coral reef habitats must be improved. This includes preventing vessel-related impacts and reducing risks of damage to coral reefs from activities conducted, funded, or approved by Federal agencies.

Significant actions implemented in the past two years are reducing the impacts of coastal use and conserving reefs. These include limiting certain activities – prohibiting jet skis in sensitive areas off Puerto Rico, imposing a moratorium on water sports in CNMI, and banning the feeding of reef wildlife off Florida. Also, permanent mooring buoys have been installed or replaced (Fig. 21) and a national inventory of abandoned vessels was created to aid restoration activities.

To help mariners avoid anchoring in reef areas, standard symbols for No Anchoring Areas and Coral Reefs were added to the catalog of chart symbols of the International Hydrographic Organization, and the first mandatory 'No Anchoring Area' was established for the Flower Garden Banks National Marine Sanctuary. Finally, several large legal settlements and restorations were obtained for accidents involving coral damage.

Reduce Pollution – Another part of the National Action Plan called for significantly reducing or eliminating the amounts, sources, and cumulative impacts of contaminants in the water. Over the past two years, there has been substantial Federal assistance for



Figure 20. Globally, seahorses are highly targeted by the marine aquarium trade (Photo: Roberto Sozzani).

significant conservation actions. For example, the U.S. Department of Agriculture signed agreements and contracted with landowners and operators to assure the best conservation practices will be applied to nearly 1,776 mi² of agricultural lands over the next 5-10 years to reduce non-point source water pollution near coral reefs.

And since 2000, tons of marine debris have been cleared from Hawaiian coral reefs and beaches. Several million people helped clean debris from beaches elsewhere.

Minimize Alien Species – Since alien species are an emerging issue, the Bishop Museum, NOAA, the USFWS, and other agencies and non-governmental agencies have prepared a variety of education materials and have committed to building an early warning system for coastal invasive species. Through the DoD's Legacy Program, The U.S. Navy initiated a survey of microflora in ballast tanks on its vessels in 2002.

Restore Damaged Reefs – Restoring of coral reefs injured by vessel groundings is an important part of the National Action Plan. New techniques and approaches for improving restoration need to be developed.

Federal and State agencies have implemented a wide range of coral restoration projects. In one of the largest restoration operations to date, USCG, NOAA, the Department of Energy, Department of Interior, and American Samoa cooperated and successfully removed nine long-line fishing vessels from Pago Pago Harbor that were grounded during a 1991 cyclone. And in 1999-2000, USFWS contractors removed most of the ship debris from a 1993 grounding of a

Figure 21. Installing mooring buoys at Johnston Atoll National Wildlife Refuge (Photo: James Maragos).





Figure 22. A diver inspects the engine of the Taiwanese longliner fishing vessel that grounded on Rose Atoll (Photo: James Maragos).

Taiwanese longliner at Rose Atoll (Fig. 22). The Waikiki Aquarium and the State of Hawai'i are initiating a pilot project to restore damaged coral habitat in Kealahou Bay on the island of Hawai'i. NOAA and the State of Florida reconstructed four spurs of an ancient coral reef in the Florida Keys National Marine Sanctuary that had been damaged by the grounding of a 47 m vessel.

Reduce Global Threats to Coral Reefs – The National Action Plan called for diverse activities to protect and conserve reefs internationally, with an emphasis on capacity-building and technical assistance. The United States assisted 25 countries in the wider Caribbean, Central America, South East Asia, South Pacific, East Africa, and Middle East regions to improve their capacity for sustainable management and conservation.

Additionally, a number of international activities received U.S. funding and technical assistance, including support for Mexico's first National Marine Park. Jamaica's Ridge to Reef Project received funding to integrate land-based management practices with coastal water quality. NOAA strengthened the International Coral Reef Initiative and supported several Global Coral Reef Monitoring Network initiatives.

Reduce Impacts from International Trade in Coral Reef Resources – The United States is the primary consumer of live coral and marine fishes for the aquarium trade, and coral skeletons and precious corals for curios and jewelry. Executive Order 13089 and the National Action Plan charge the USCRTF with addressing the degradation and loss of coral reefs arising from commerce in coral reef species and products.

The USCRTF International Working Group developed and recommended that Congress adopt new regulations for a comprehensive strategy to reduce adverse impacts of trade. Among other activities, the United States provided financial and technical support for the Pacific Regional Workshop "Sustainable Management of the Marine Ornamental Trade" held in Fiji, and the "International Coral Trade Workshop; Development of Sustainable Management Guidelines" held in Jakarta, Indonesia.

Create an Informed Public – The National Action Plan called for a focused, multi-level outreach campaign to prevent further declines in coral reef health. Since FY00, USCRTF State and Territorial agencies have expanded their education and public outreach projects for coral reef conservation and protection (Fig. 23). Many have been assisted by Federal grants. For example, Hawai'i, Guam, and the CNMI produced *State of the Reef* reports and coral reef educational CDs.

Improve Coordination and Accountability – Primarily, the USCRTF was created to improve coordination and accountability among Federal Agencies responsible for coral reefs. The National Action Plan established a small, interagency staff to coordinate the shared Federal agency tasks identified in the Executive Order.

Since FY00, this staff has coordinated the submission of annual agency annual program reports and accomplishments, crosscutting budget initiatives on coral reef conservation. It also developed the process for the public inquiry about the agency response to issues and concerns relating to Federal agency actions for coral reef protection. This same group has facilitated each Task Force meeting and

Figure 23. Elementary school children learn about coral reefs through an educational program (Photo: FGBNMS).



helped implement specific USCRTF-related actions at regional and local levels to strengthen the cohesive national strategy for coral reef conservation.

The Coral Reef Conservation Fund (The Fund) –

The Coral Reef Conservation Act of 2000 authorized NOAA to enter into an agreement with the National Fish and Wildlife Foundation, a non-profit organization, to establish and administer a fund to support coral reef conservation. In 2001 the Fund provided approximately \$2 million in



Figure 24. Staghorn coral thickets off of Southeast Florida seem to be in good condition despite their proximity to highly populated areas (Photo: NCRI).

grants to support the development of education and public outreach projects.

Recommendations and Conclusions

Critical information is needed to conserve and protect U.S. coral reefs. Basic mapping has yet to be done for over 85% of all U.S. reefs. As a result, data in this report referring to the area covered by coral reefs, including the percent under no-take provisions, are mostly estimates from a variety of sources. The figures vary widely mostly because of inadequate and inaccurate base maps and charts.

Aside from ongoing mapping efforts, many reef areas need basic assessment and biotic inventories. Comparable long-term monitoring needs to be sponsored and integrated across regions. Managers of reefs with recognized high threats need more resources to mitigate impacts from degraded water and substrate quality, overfishing, invasive species, or other anthropogenic stresses. They must be prepared to take bold conservation measures to reverse present trends.

To track changes in ecosystem health and evaluate the effectiveness of conservation measures, grants

to State and Territorial agencies need to be continued for the next 5-10 years. Public awareness and education and efforts need to continue at a high level to encourage a new ethic of sustained use of coral reef ecosystems.

This report finds that:

- U.S. coral reef areas are extensive.
- Healthy reef ecosystems are critical for local and regional economies.
- All jurisdictions still have some reefs in good to excellent health (Fig. 24). These need conservation.
- All shallow reefs near urbanized coasts are degraded to some extent. These need restoration.
- Areas next to densely populated shorelines generally have poorer water quality than those far from human habitation. Where water quality is fair to poor, reef ecosystems are degraded. Water quality needs to be improved in those areas, and measures taken to maintain the water quality of areas where reef condition is now deemed good to excellent.
- Coastal development, runoff, and sedimentation have impacted reefs around most high islands. This needs to be minimized.
- Fishing pressure has been a primary factor impacting reef ecosystems for decades. There is evidence that overfishing has changed ecosystem structure and function. Different and effective methods of management need to be implemented.
- Remote reefs with little coastal development, good water quality, and low fishing pressure are in excellent health, as characterized by many large fish and generally high species diversity. These need to be studied and preserved.
- Marine refuges with no-take provisions produce more and larger fish. With enough time, they can conserve reef communities and long-lived species, producing trophy-sized apex predators. More no-take areas need to be implemented within MPAs to reach the USCRTF goal of 20% protection.
- Some existing marine protected areas are not protecting reefs. Regulations within these need to be strengthened and adequately enforced.
- Enforcement is critical. It needs to be expanded and made more effective.

